DIRECT DRIVE SUSPENSION

Related Applications

[0001] This invention relates to and claims priority as a CONTINUATION-IN-PART of co-pending U.S. Patent Application Number 10/116,883 entitled " SKID STEER VEHICLE WITH AXLE HOUSINGS DIRECTLY DRIVEN BY A HYDRAULIC MOTOR", as a CONTINUATION-IN-PART of co-pending U.S. Patent Application Number 10/136,265, entitled "SKID STEER VEHICLE WITH AXLE HOUSINGS HAVING A DOUBLE GEAR REDUCTION", and as a CONTINUATION-IN-PART of co-pending U.S. Patent Application Number 10/143,601 entitled "SKID STEER VEHICLE WITH DIRECT DRIVE" (hereinafter "related applications")

Field of the Invention

[0002] The invention relates generally to work vehicles. More particularly, it relates to direct drive suspensions for such vehicles.

Background of the Invention

[0003] Skid steer loaders were first invented about 30 years ago to fill a need for a small highly maneuverable vehicle that was capable of carrying an implement mounted on loader arms. Skid steer loaders are typically small vehicles, on the order of 10 to 14 feet long, that rest on four or more wheels, at least two of which being disposed on each side of the vehicle.

[0004] In order to turn these vehicles, the wheels on opposing sides of the skid steer loader are driven at different speeds. This causes the faster moving wheels on one side to advance that side over the ground faster than the other side on slower moving wheels. The effect is to turn the vehicle toward the wheels

on the slower moving side. Since the wheels are not turnable with respect to the vehicle, the vehicle turns by skidding slightly, hence the name "skid steer loader." In the extreme case the wheels on one side of the vehicle can turn in the opposite direction at the same speed as the wheels on the other side of the vehicle. When this mode of operation is selected, the skid steer loader will rotate in place about a vertical and generally stationary rotational axis.

[0005] This ability to change direction by rotating about an axis within the footprint or perimeter of the loader itself was the primary reason why the skid steer loader achieved its great success.

[0006] This mode of turning by skidding permits the skid steer vehicle to operate within confined spaces to provide workers within those spaces the added power that a mobile lifting arm or blade can provide.

[0007] The skid steer vehicle is used inside buildings that are under construction or are being fabricated. The skid steer vehicle can carry material and tools quite close to an inside work location right to where workers are fabricating the building, making modifications to the building or other related work. Larger vehicles that have lifting and load-carrying abilities, such as bulldozers, backhoes, front wheel loaders and the like do not have the same ability.

[0008] Backhoes with their large rear tires and wide stance cannot easily go through doorways or apertures of buildings that are under construction. Furthermore, their stance is typically too wide to pass through the doorways and their height as well is too large, typically on the order of 10-12 feet off the ground -- too large to pass through building doorways or wall openings. Backhoes turn by steering their front wheels with respect to their chassis, giving them a typical turning radius of 25-45 feet, still much too large to use conveniently inside a building

[0009] Wheel loaders have an extremely wide stance and large bucket, permitting them to carry and move large loads at relatively high speeds over

broken ground. Wheel loaders are intended for such locations as road construction sites, rock quarries, steel mills and other outside locations where large capacity, relatively high speed vehicles are beneficial.

[0010] Articulated wheel loaders are also constrained by their method of steering: they include two-piece chassis that bend slightly in the middle permitting them to turn in a circle with a radius of about 30-50 feet. This would require an extremely large area in which to turn around, and they would be dangerous in crowded work areas. With a height of about 10-15 feet, they cannot pass through opening or doorways to be used inside buildings to carry tools and supplies and support inside workers.

[0011] The only truly practical work-horse for in-building work and work in close proximity to workers is the skid steer loader, and it has been used for those purposes for many years.

[0012] One big advantage to skid steer loaders is their low height, typically no more than 8 or 9 feet. This is low enough to permit the vehicle to pass through doorways. A further advantage to skid steer vehicles is their narrow width. They are typically less than six feet wide, permitting them to pass though double door ways into commercial buildings under construction. In this manner, they can easily ferry tools and material from larger vehicles and storage areas outside the building into the building itself where they can be delivered to the workers.

[0013] Another beneficial feature of skid steer vehicles is their ability to turn in place. By turning in place, skid steer vehicles can often avoid backing up at all when inside a building permitting them to maneuver quite carefully through and around work stations, workers, and piles of materials when moving about inside.

[0014] Two significant drawbacks to skid steer vehicles are their drive systems and their rigid suspensions.

[0015] Skid steer vehicles typically use chain drives to connect hydraulic motors to wheels. These chains are placed in enclosed "chain tanks" that are

filled with liquid lubricants. Hydraulic motors extending into the tanks engage chains that extend forward and aft to the forward and the rear drive wheels.

[0016] Each side of the vehicle has a chain tank with its associated motor and drive wheels, the chain tank extending fore-and-aft along each side of the vehicle.

[0017] As the vehicles are driven, the rapid back-and-forth of the drive systems tighten and slacken the chains repeatedly. Each time the hydraulic motor is reversed to change the vehicle's direction, the chain is slackened in one direction and jerked taught to begin traveling in the opposite direction.

[0018] This repeated jerking of the chains and the high loads provided by the hydraulic drive motors cause the chains to wear rapidly and require replacement frequently. The down-time to replace the chains, the cost of disassembling and reassembling the vehicles and the cost of new chains themselves, all add significantly to the total cost of ownership of a skid-steer vehicle.

[0019] Chain drive skid steer vehicles are typically unsprung. The wheels of the vehicles are most commonly supported on fixed rotating axles that extend outward through the sidewalls of the chassis. The sidewalls of the skid steer chassis itself are solid steel plates having apertures through which the axles pass. The axles, in turn, are supported on bearings that are fixed to the side walls.

[0020] The unsprung nature of the skid steer vehicles poses a problem in itself, since it prevents the skid steer from absorbing the shocks caused by travel over irregular terrain. The short wheelbase and narrow width of a skid steer compounds the problem. At speeds above about 8-10 miles per hour over rough terrain, the skid steer vehicles tend to pitch and roll excessively. For this reason, skid steer vehicles tend to be continuously operated at speeds not exceeding six miles per hour.

[0021] Given their difficult performance at speeds much in excess of six or eight miles per hour, most skid steer vehicles are speed-limited by design. They

are engineered to go at a maximum speed of 10-12 miles per hour, which can be considered a general practical ground speed limit for an unsprung skid steer vehicle, even one traveling over even ground.

[0022] Six to eight miles per hour may seem a satisfactory rate of travel. For many work environments, however, it is not satisfactory. In many work environments a skid steer vehicle may have to repeatedly travel 200-400 feet, carrying buckets of soil or other materials. At 6-8 miles per hour, this distance can be quite large. In other environments, such as road construction, a work site can be several miles long. These distances pose a significant problem to the mobility and usefulness of a skid steer vehicle and sorely limit its usefulness and applicability.

[0023] Several ways of solving the dual problems of chain wear and speed have been individually proposed. In the Related Applications, the inventors have proposed using a right angle gear drive with a fore-and-aft extending driveshaft to couple the hydraulic motor to its front and rear drive wheels.

[0024] While the illustrated arrangement alleviates the wear problem by replacing the chain with a driveshaft/gearbox system, it does not provide a sprung suspension, since the forward and rear axle housings that support the front and rear axles are fixed to the chassis. The vehicle is unsprung.

[0025] In the skid steer vehicle shown in U.S. Patent Number 6,584,710, a sprung suspension is provided, which alleviates the problems due to lack of springing, but requires additional components: two more hydraulic motors, four reduction gear drive hubs, and the hydraulic conduits required to connect these components together.

[0026] What is needed is a skid steer vehicle that provides both the smooth ride provided by a sprung suspension and the durability and low maintenance of a driveshaft and gear drive system.

[0027] What is also needed is a skid steer vehicle with a sprung suspension and a chainless drive system that does not require a separate motor for each driven wheel.

[0028] It is an object of this invention to provide such a system in one or more of the embodiments described and claimed herein.

Summary of the Invention

[0029] In accordance with a first aspect of the invention, a skid steer vehicle is provided having four independent sprung suspensions. The vehicle uses a direct drive system, a system using gears and drive shafts that eliminates the need for an elongated chain tank.

[0030] Each suspension includes a gearbox that is pivotally mounted to the chassis or frame of the skid steer vehicle. The front suspensions are pivotally coupled to the chassis at their rear ends and extend forward. The rear suspensions are pivotally coupled to the chassis or frame at their front ends and extend backward. The gearboxes extend generally parallel to the ground and fore and aft, such that the pivot point where the gearboxes are pivotally coupled to the chassis or frame is at the same height as the axles extending from their free ends.

[0031] A hydraulic motor assembly is mounted on each side of the vehicle. It drives the two gearboxes and wheels on that side of the vehicle. It is coupled to the gearboxes by flexible couplings that permit the gearboxes to pivot up and down with respect to the vehicle as they are driven by the hydraulic motor assembly.

[0032] The motor preferably has a drive shaft that extends longitudinally, the front end of the drive shaft being coupled to the gearbox of the front suspension and the rear end being coupled to the gearbox of the rear suspension.

Brief Description of the Figures

[0033] Preferred exemplary embodiments of the present invention are illustrated in the accompanying drawings in which like reference numerals represent like parts throughout.

[0034] FIGURE 1 is a left side view of a skid steer vehicle with sprung direct drive suspensions in accordance with the present invention.

[0035] FIGURE 2 is a partial cross-sectional plan view of the vehicle of FIGURE 1 taken at section line 2-2 in FIGURE 1 showing the arrangement of the suspension gearboxes and hydraulic motors on both sides of the vehicle.

[0036] FIGURE 3 is a fragmentary left side view of the vehicle of FIGURES 1-2 showing the arrangement of gears within the gearbox.

[0037] FIGURE 4 is a detailed view of the left front pivot for the left front gearbox, which is exemplary of all of the pivots on the vehicle.

Detailed Description of the Invention

[0038] In FIGURE 1, skid steer vehicle 100 has a chassis 102, an engine 104 mounted in the chassis, four wheels including left-side wheels 106, 108 and right-side wheels 110 and 112 (FIGURE 2), an operator compartment 114 surrounded by a roll-over protection system 116, a pair of loader lift arms of which left-side arm 118 is shown in FIGURE 1. An implement is attached to the free ends of the loader arm, here shown as bucket 117.

[0039] The lift arms are pivotally coupled to the chassis and are raised by one or more loader lift arm cylinders 120. The bucket is pivotally coupled at the end of the lift arms by one or more bucket cylinders 122.

[0040] The chassis or frame 102 is supported on the ground by wheels 106, 108, 110 and 112. The wheels may have solid or pneumatic tires. While it is not illustrated here, a continuous loop track may be wrapped around the wheels to provide better traction on rough terrain.

[0041] The operator compartment 114 is preferably defined by a cage, having a plate for a roof and expanded metal mesh on its rear, left and right sides. It is these elements that constitute the roll over protection system. The front of the compartment is preferably open to permit the operator easy entry and egress.

[0042] The chassis is preferably formed of several steel sheets that are welded or bolted together to form what resembles a rectangular bucket having four sidewalls, a floor pan and an open top in which the engine, hydraulic drive pumps and drive motors are mounted.

[0043] Engine 104 is coupled to and drives several hydraulic drive pumps 124 that provide hydraulic fluid under pressure. This fluid is used to drive the vehicle over the ground and to operate the hydraulic cylinders. The hydraulic cylinders, in turn, raise and lower the loader arms and tilt the bucket.

[0044] FIGURE 2 is a plan view of the chassis in partial cross-section, the section being taken generally along section line 2-2 in FIGURE 1. FIGURE 2 illustrates the arrangement of the vehicle's suspensions in relation to the vehicle's chassis.

[0045] The vehicle suspension system includes left front, left rear, right front and right rear gearboxes 200, 202, 204, and 206, respectively. Each gearbox is pivotally coupled to the chassis to pivot about a generally lateral or side-to-side axis. The two front gearboxes pivot about a common front lateral pivotal axis 208 and the two rear gearboxes pivot about a common rear lateral pivotal axis 210. Pivot joints 212, 214, 216 and 218 are provided that couple gearboxes 200, 202, 204, 206, respectively, to the chassis. These joints insure that the gearboxes pivot with respect to the chassis about axes 208 and 210.

[0046] The gearboxes extend in a generally horizontal plane, such that the rotational axes of the wheels supported by the gearboxes are at the same height as (and parallel to) the pivotal axes 208 and 210 of the gearboxes when the suspensions are at their preferred operating height. This position is shown in FIGURE 1.

[0047] Gearboxes 200, 202, 204, 206 are supported by springs 220, 222, 224, 226, and damped by dampers 230, 232, 234, 236, respectively, that extend between and are coupled to the chassis and to their respective gearboxes. In the FIGURES, the illustrated springs are coil springs that extend around their associated dampers. In the FIGURES the dampers are illustrated as hydraulic cylinders around which the springs are coiled.

[0048] In an alterative embodiment, the springs may be eliminated and springing provided by a gas-charged accumulator coupled to the hydraulic cylinders. This gas charge may be internal to the cylinders or it may be in an external accumulator. In yet another alternative embodiment, the springs may be mounted separately from the dampers. In other alternative embodiments, the springs may be leaf springs or torsion springs.

[0049] The left side of the vehicle is provide with hydraulic motor assembly 238 that is coupled to and drives left side gearboxes 200 and 202. The right side of the vehicle is provided with hydraulic motor assembly 240 that is coupled to and drives gearboxes 204 and 206.

[0050] The hydraulic motors assemblies 238, 240 are fixed, respectively, to the left and right sides of the vehicle, and are disposed at generally the same height as pivotal axes 208 and 210. They are also preferably disposed between axes 208, 210 and between their gearboxes as well.

[0051] Each motor is coupled to a forwardly extending driveshaft 242 and a rearwardly extending driveshaft 244. These shafts rotate about axes that are

preferably parallel to the longitudinal axis of the vehicle itself and also perpendicular to and coplanar with axes 208 and 210.

[0052] Driveshaft 242 extends forward from the hydraulic motor assembly and engages flexible coupling 246. Driveshaft 244 extends rearwardly from the hydraulic motor assembly and engages flexible coupling 248. In an alternative embodiment, drive shafts 242 and 244 may be the same drive shaft, extending completely through the hydraulic motor assembly.

[0053] Flexible couplings 246 and 248 preferably include constant velocity joints, Hooke's joints, or, alternatively, double Hooke's joints, Carden joints or universal joints, although other joints or couplings permitting a shaft angular misalignment of 15 degrees or so would be acceptable.

[0054] Drive shafts 250 extend between and couple flexible couplings 246 and gearboxes 200, 204. Drive shafts 252 extend between and couple flexible couplings 248 and gearboxes 202, 206.

[0055] FIGURE 3 illustrates how power is transferred from drive shafts 250 and 252 to the wheels of the vehicle. FIGURE 3 shows, in partial cutaway, the interior of the front and rear gearboxes 200, 202 on the left side of the vehicle. Since the arrangement on the right side of the vehicle is identical, but a mirror image, it has not been separately pictured in this application.

[0056] Gearbox 200 includes an outer casing 300 that is bolted to an inner casing 302. The inner and outer casings not only enclose the internal gears, but support the internal shafts and gears. Outer casing 300 supports the outboard ends of the shafts and inner casing 302 supports the inboard ends of the shafts. The casings are preferably cast iron that is subsequently machined to provide supports for the shafts and shaft bearings.

[0057] Gearbox 200 includes a bevel pinion gear 304 that is supported on bearings for rotation and receives driveshaft 250. Drive shaft 250 drives gear 304 in rotation. Gear 304, in turn, engages bevel gear 306 which is fixed on shaft 308

for rotation. Spur gear 310 is also fixed to shaft 308 and rotates together with gear 306, whenever gear 306 is driven by gear 304.

[0058] A second gear shaft 312 is provided in gearbox 200, to which gears 314 and 316 are fixed. Spur gear 310 is engaged to and drives gear 314. Gear 316 is fixed to shaft 312 and turns together with gear 314 whenever gear 314 is driven by gear 310.

[0059] An axle 324 is provided in gearbox 200 to which gear 326 is fixed. Gear 326 is engaged to and driven by gear 316. The outboard end 328 of axle 324 extends out of gearbox 200 and includes a flange 330 to which wheel 106 is removably fixed. Thus, through the internal gear train of gearbox 200, hydraulic motor assembly 238 drives wheel 106 in rotation.

[0060] In a similar fashion, gearbox 202 includes an outer casing 332 that is bolted to an inner casing 334. The inner and outer casings not only enclose the internal gears, but support the shafts that extend from the gears for rotation. Outer casing 332 supports the outboard ends of the shafts and inner casing 334 supports the inboard ends of the shafts.

[0061] Gearbox 202 includes a bevel pinion gear 336 that is supported on bearings for rotation and receives driveshaft 252. Drive shaft 252 drives gear 336 in rotation. Gear 336, in turn, engages bevel gear 338 which is fixed on shaft 340 for rotation. Spur gear 342 is also fixed to shaft 340 and rotates together with gear 338, whenever gear 338 is driven by gear 336.

[0062] A second gear shaft 344 is provided in gearbox 202, to which gears 346 and 348 are fixed. Spur gear 342 is engaged to and drives gear 346. Gear 348 is fixed to shaft 344 and turns together with gear 346 whenever gear 346 is driven by gear 342.

[0063] An axle 356 is provided in gearbox 202 to which gear 358 is fixed. Gear 358 is engaged to and driven by gear 348. The outboard end 360 of axle 356 extends out of gearbox 202 and includes a flange 362 to which wheel 108 is

removably fixed. Thus, through the internal gear train of gearbox 202, hydraulic motor assembly 238 drives wheel 108 in rotation.

[0064] By shifting the positions of the bevel gears as shown in FIGURE 3, the gear trains in each gearbox are arranged such that hydraulic motor assembly 238 drives wheel 106 and 108 in the same rotational direction. Were gearboxes 200 and 202 mirror images of each other, they would rotate in opposite directions. Hydraulic motor assembly 238 is bi-directional and can be driven in both directions to permit front wheel 106 and rear wheel 108 to rotate both forward and reverse.

[0065] Each pair of mating gears in both of the gearboxes 200, 202 is a continuously meshing, speed-reducing gear set. Each gear set in gearbox 200 has a corresponding mirror gear set in gearbox 202 providing the same reduction ratio and having the same number of teeth. Each shaft and axle in each gearbox are coplanar. They are also parallel to one another, with the exception of gears 304 and 336.

[0066] Pivot joints 212 and 214 are provided to pivotally couple gearboxes 200 and 202, respectively, to chassis 102.

[0067] Left front pivot 212 is shown in FIGURE 4, which illustrates one possible construction of the pivot joints in more detail. The structure and arrangement shown in FIGURE 4 and described below is typical of the other pivot joints 214, 216, and 218 of the vehicle. It should be understood that any alternative joint that constrains the gearboxes to pivot about a pivot axis with respect to the chassis of the vehicle would be equally useful as a pivot joint.

[0068] Joint 212 is formed of a cylindrical elongate member 400 that is fixed to and preferably formed integrally with gearbox 200 and extends laterally inward away from the gearbox. Member 400 extends through the sidewall 402 of chassis 102 into the interior of vehicle 100.

[0069] Member 400 is surrounded and supported by anti-friction bushing 404. Bushing 404, in turn, is supported inside housing 406, which is fixed to and extend inward from sidewall 402 of chassis 102. Bushing 404 is preferably cylindrical, both inside and outside and is preferably made of a softer material than the material of member 400, such as brass, bronze, light alloy, or a polymer.

[0070] Housing 406 is preferably a cylindrical tubular member, fixed to the inner surface of sidewall 402 and extending laterally inward, supporting bushing 406 and member 400.

[0071] Depending upon the applied loads, a suitable high pressure lubricant may be injected between housing 406 and bushing 404 and between bushing 404 and member 400 to reduce wear between the components.

[0072] Member 400 is secured to the vehicle by a plate 408 that is fixed to the end of member 400 with threaded fasteners 410. This plate is sized slightly larger than the inner passageway through housing 406 and thus cannot be withdrawn. Axial loads on member 400 are transferred to plate 408, which in turn transmits the loads to housing 406 and sidewall 402, thus preventing member 400 from being withdrawn from housing 406.

[0073] Pivotal axes 208 and 210 are defined by member 400 and housing 406. Gearbox 200 and 202 are configured such that the center of pivot of the gearboxes is coaxial with the pivotal center of flexible couplings 246 and 248. The pivotal center of flexible coupling 246 is the projected point of intersection of driveshaft 242 and driveshaft 250. The pivotal center of flexible coupling 248 is the projected point of intersection of driveshaft 244 and driveshaft 252. Thus, the projected point of intersection of drive shafts 242 and 250 is on axis 208, and the projected point of intersection of drive shafts 244 and 252 is on axis 210.

[0074] The axles of the two front gearboxes have the same rotational axis when the wheels front gearboxes are in the same pivotal positions. Similarly, he

axles of the two rear gearboxes have the same rotational axis when the two rear gearboxes are in the same position.

[0075] Each of the four gearboxes may be pivoted to a central pivotal position in which all the gearboxes are generally parallel to the ground with the axles and the pivotal axes 208 and 210 at the same height. In this position, the vehicle is level and equally supported by each gearbox. In addition, the rotational axes of all the axles and the pivotal axes 208 and 210 are coplanar.

[0076] While the embodiments illustrated in the FIGURES and described above are presently preferred, it should be understood that these embodiments are offered by way of example only. The invention is not intended to be limited to any particular embodiment, but is intended to extend to various modifications that nevertheless fall within the scope of the appended claims.

[0077] For example, the hydraulic drive motor assembly may include a high speed, low torque hydraulic motor, or a low speed, high torque hydraulic motor. The motor assembly may include one or more integral reduction gear sets. It may include a mechanically shiftable gear set shiftable between a low speed range and a high speed range. It may be shiftable between two gear ranges by changing the position of an internal swash plate from a high speed, low torque speed range in which the motor has a lower specific displacement, to a low speed high torque speed range in which the motor has a higher specific displacement.